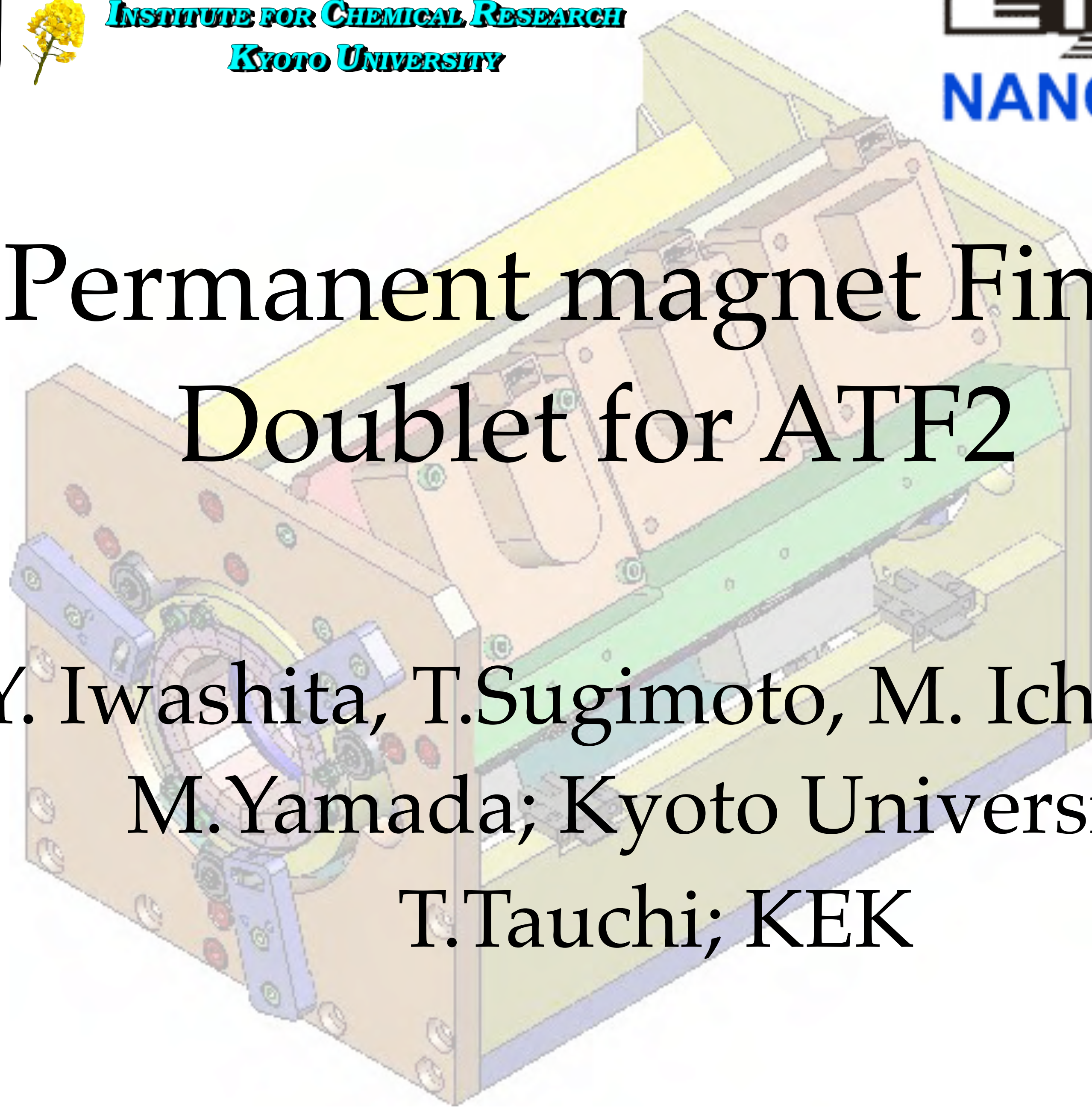
Accelerator Laboratory
Advanced Research Center for Beam Science
Institute for Chemical Research
Kyoto University

NANOBEAM'08

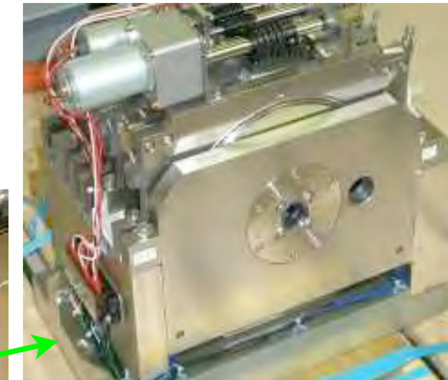


Permanent magnet Final Doublet for ATF2

Y. Iwashita, T.Sugimoto, M. Ichikawa, M.Yamada; Kyoto University
T.Tauchi; KEK

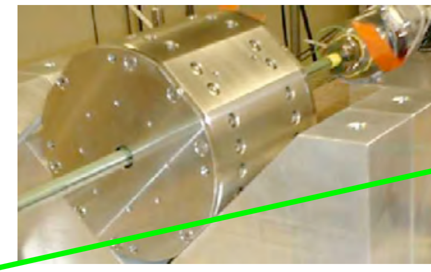
Permanent Magnet Study Short History

2002~2005 First R&D program for FFQ



Permanent Magnet Quadrupole for Final Focus

Lens in a Linear Collider

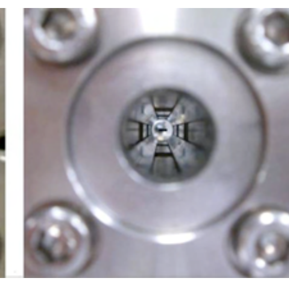


2002 Fixed strength PMQ

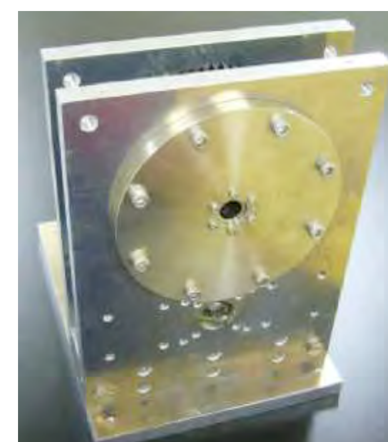
2003 Adjustable PMQ (double ring)

2004 Measurement and fine tuning

2005 Higher gradient at small bore



2006~2009 Second R&D program



Development and Application of PMQ for Linear

Collider and Neutron optics

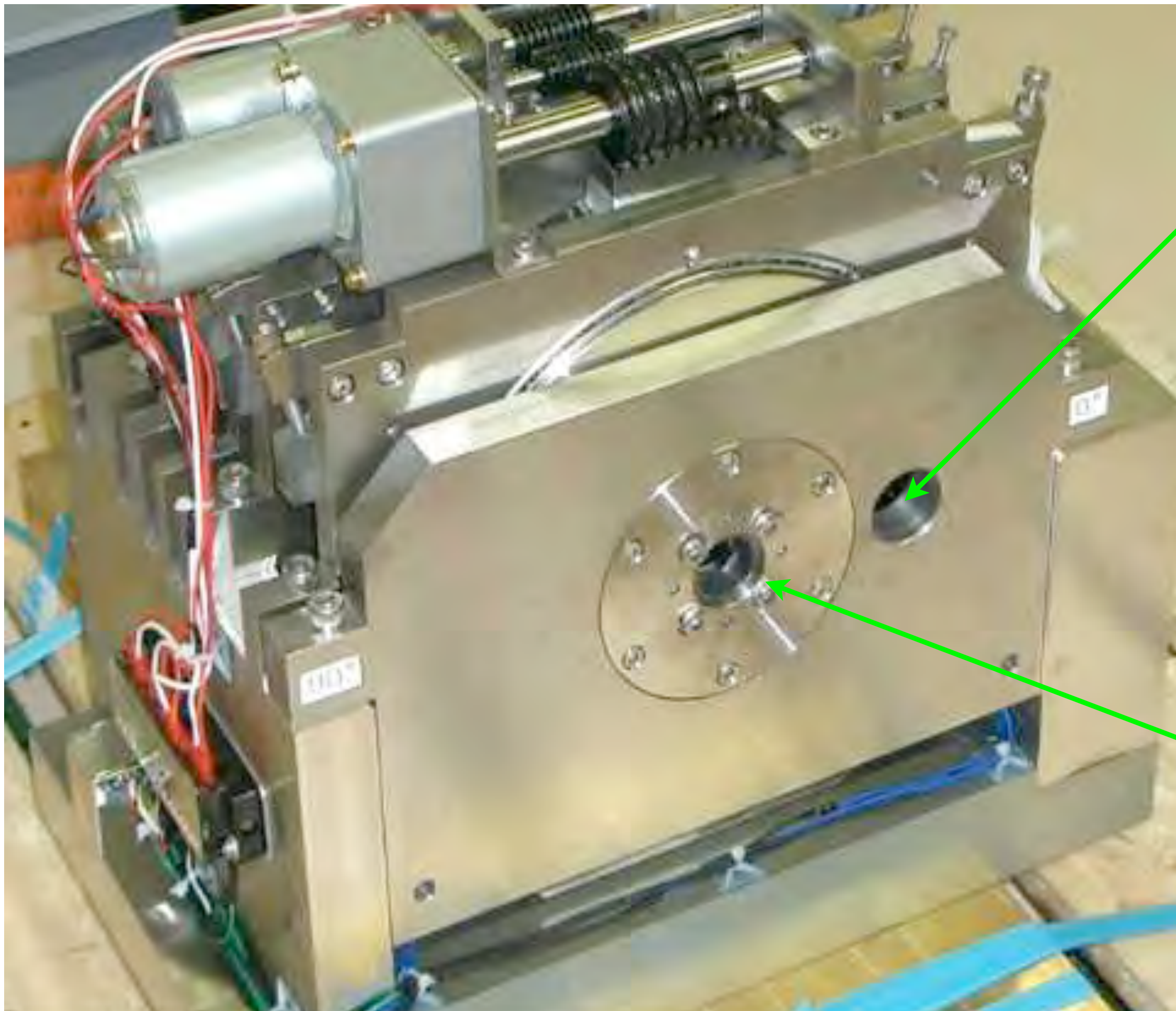
2006 Half scale Model of Rapid Cycling

Sextupole

2007~Adjustable PMQ（2nd model）

2008 ...

The 20mr Variable FFQ Magnet

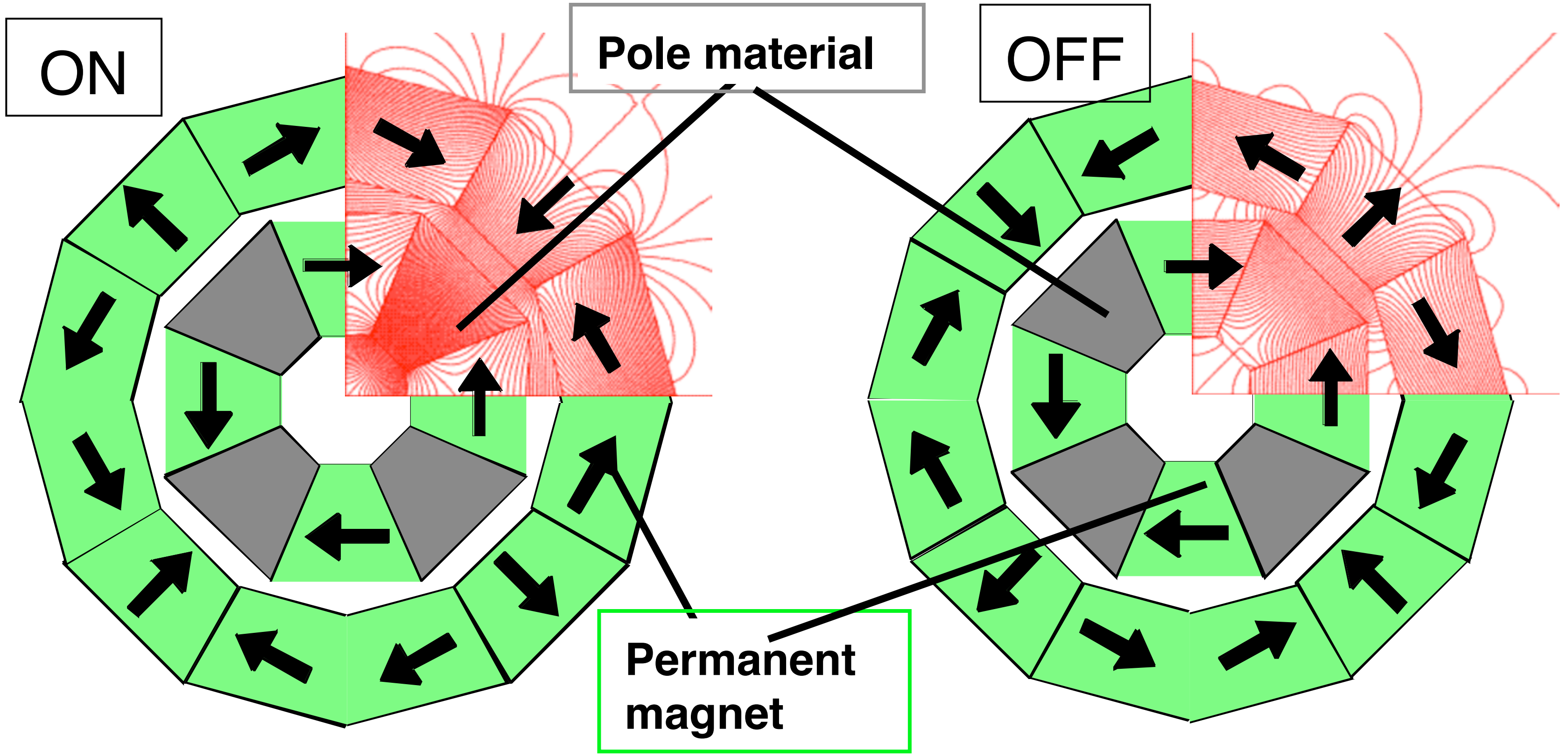


hole for outgoing beam

hole for incoming beam

Double Ring Structure

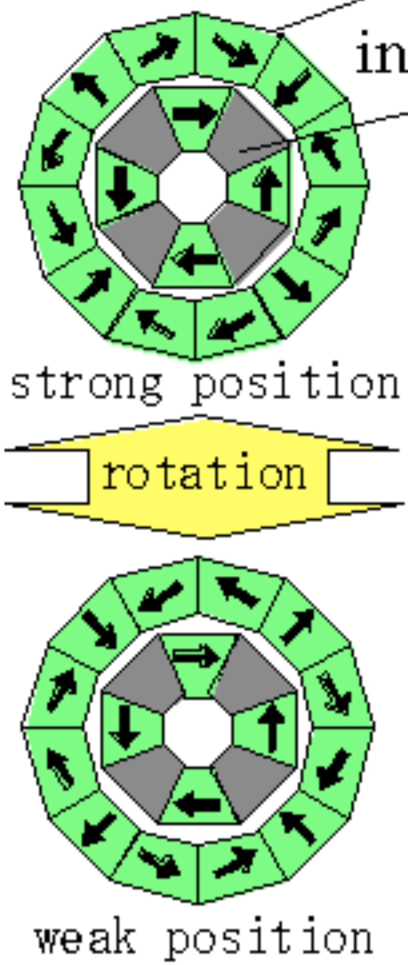
First Quadrant shows the flux plot.

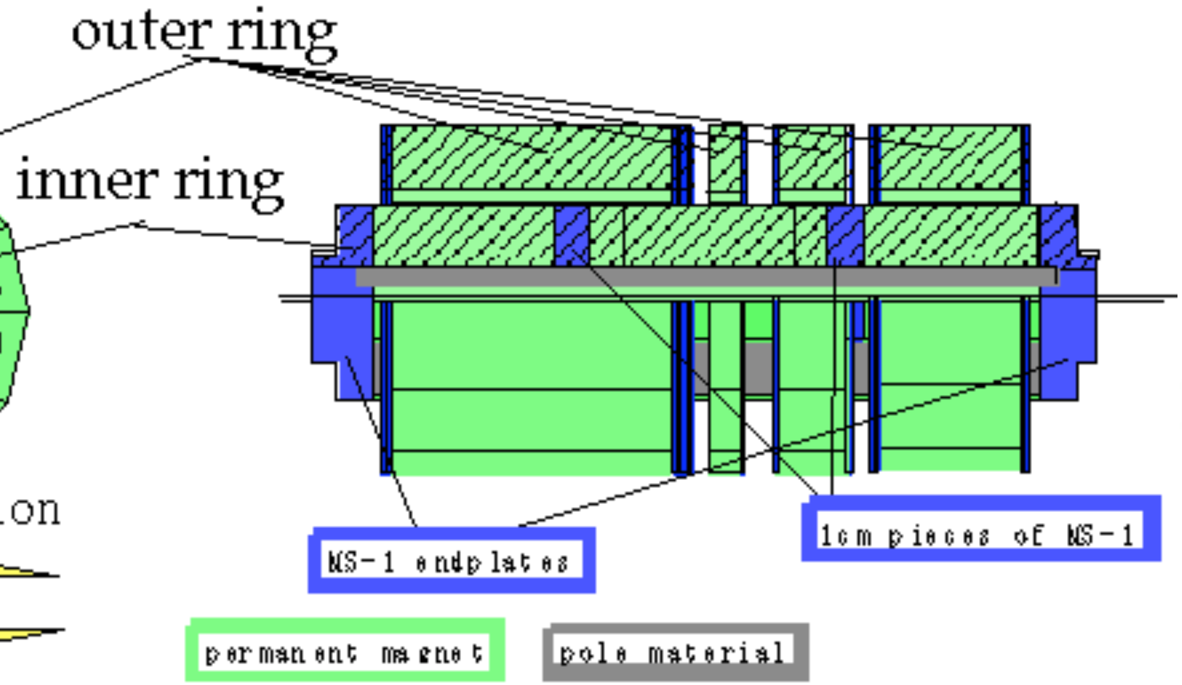


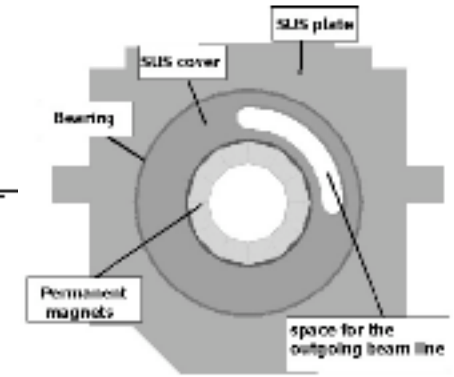
The double ring structure

PMQ is split into inner ring and outer ring. Only the outer ring is rotated 90° around the beam axis to vary the focal strength.

Adjustable Permanent Magnet Quadrupole

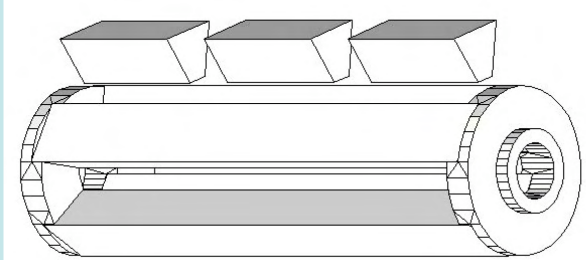






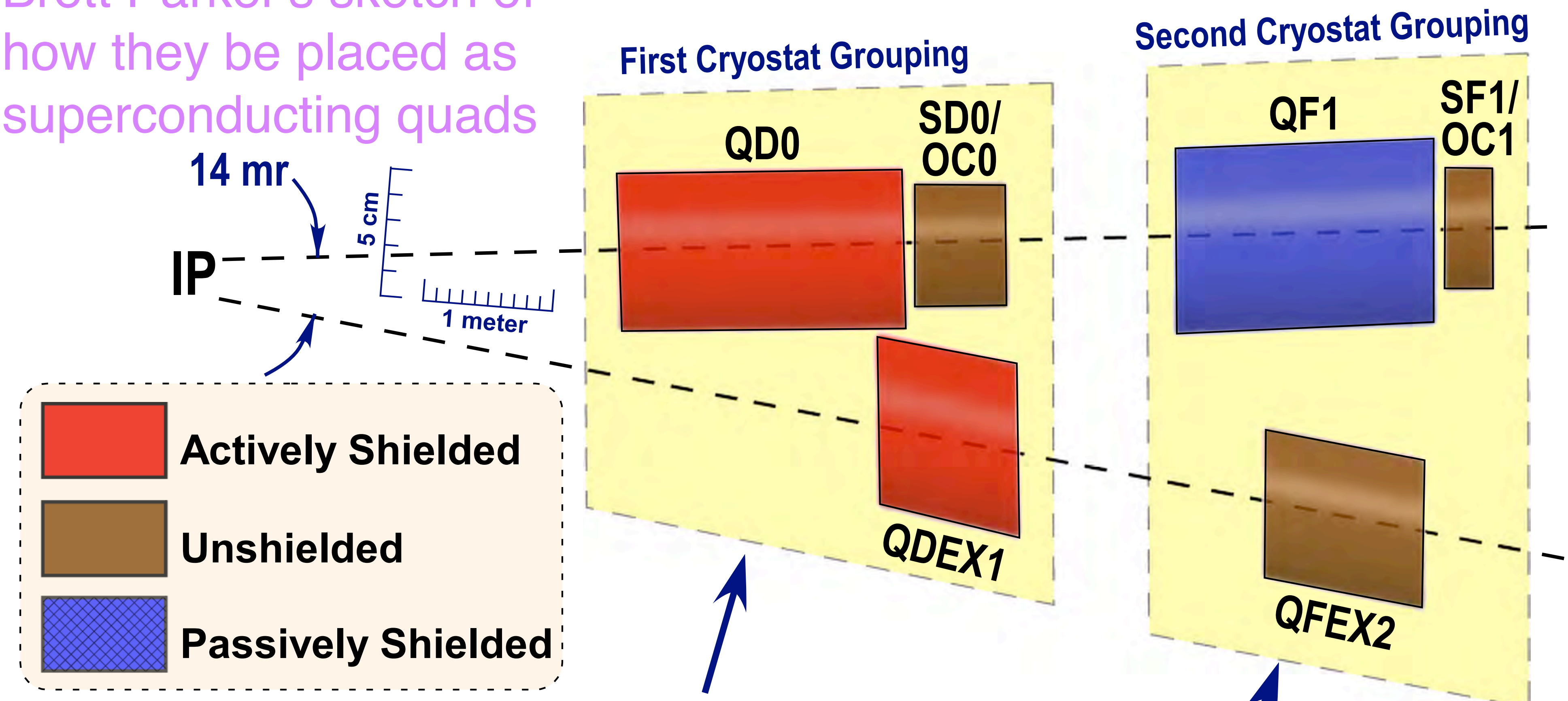
The PMQ is composed of an inner ring and four outer rings (Double Ring Structure). Only the outer rings are rotated in order to change the integrated gradient. The fixed inner ring suppresses any errors caused by rotation of outer rings.

Permanent Magnet (NEOMAX38AH)



Post Valencia 14 mr Magnet Layout Compatible with Push-Pull

Brett Parker's sketch of how they be placed as superconducting quads



One of these magnet groups is needed in both ends of each detector (move with experiment, not shared).

One of these magnet groups is needed on each side of the common push-pull IR hall (fixed position, experiments share).

For actively shielded coils the shield is run in series with the main quadrupole current but with a trim circuit shunt power supply for fine adjustment.

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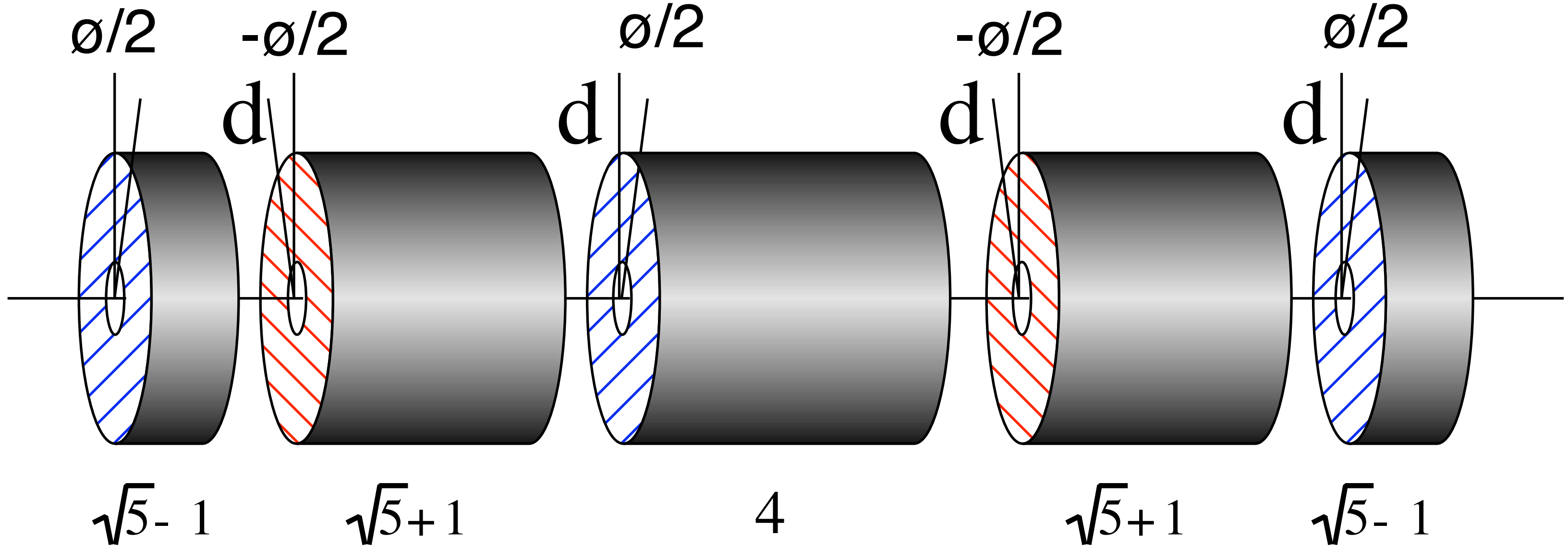
Gluckstern's skewless variable PMQ



$$M = R \bullet M2 \bullet R^{-2} \bullet M1 \bullet R^{2} \bullet M0 \bullet R^{-2} \bullet M1 \bullet R^{2} \bullet M2 \bullet R^{-1}$$

$$\text{4x4 matrix: } M = \begin{pmatrix} Mxx & O^5 \\ O^5 & Myy \end{pmatrix} \text{ when } d=0.$$

R.L. Gluckstern and R.F. Holsinger: Adjustable Strength REC Quadrupoles, IEEE Trans. Nucl. Sci., Vol. NS-30, NO. 4, August 1983, http://epaper.kek.jp/p83/PDF/PAC1983_3326.PDF

Test at ATF2 – replace QD0

Req'd spec for QD0: L=45cm, ø50mm, G=13T/m

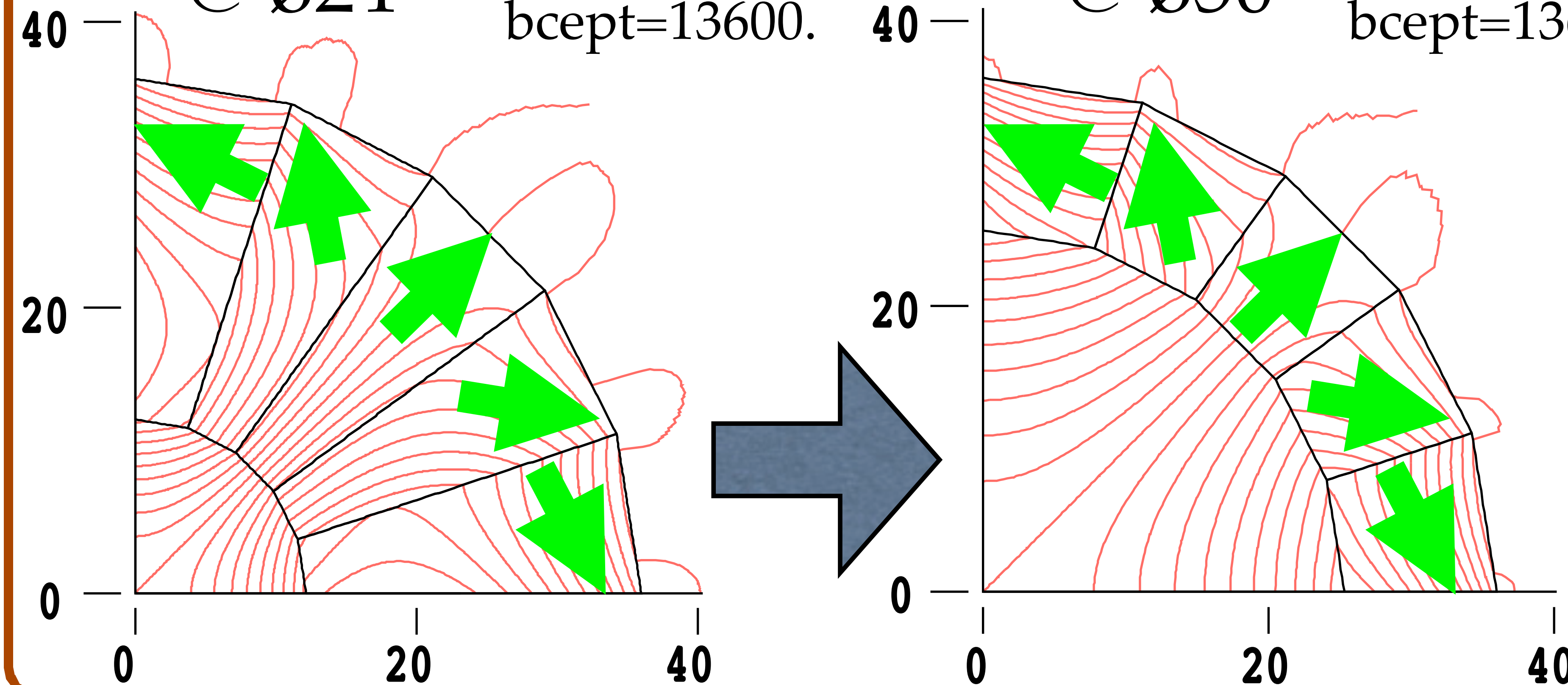
OD: ø72 (=2x(56-20)) 14mr x 4m=56mm

140T/m @ ø24

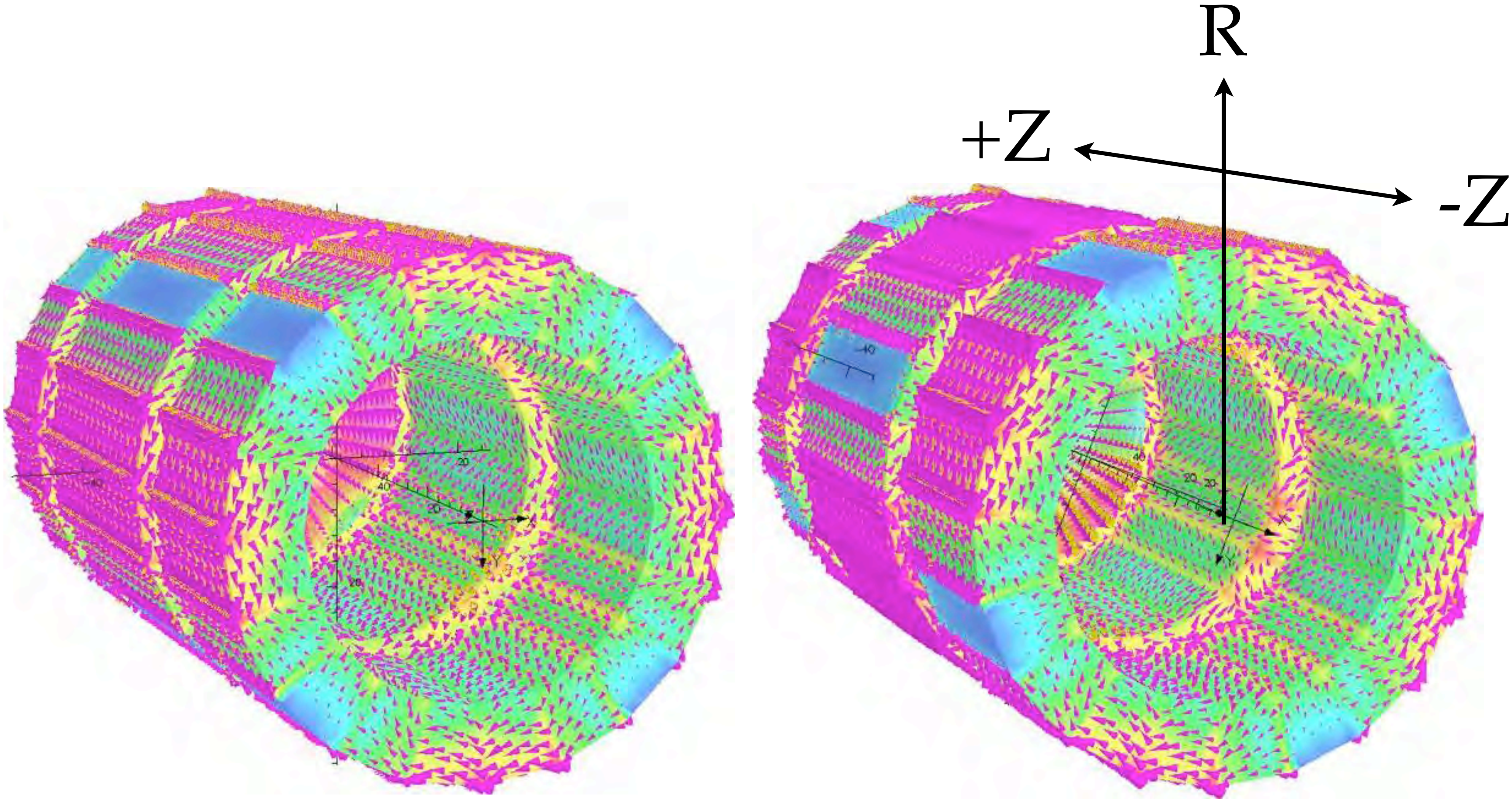
48H
hcept=-12890,
bcept=13600.

30T/m @ ø50

48H
hcept=-12890,
bcept=13600.



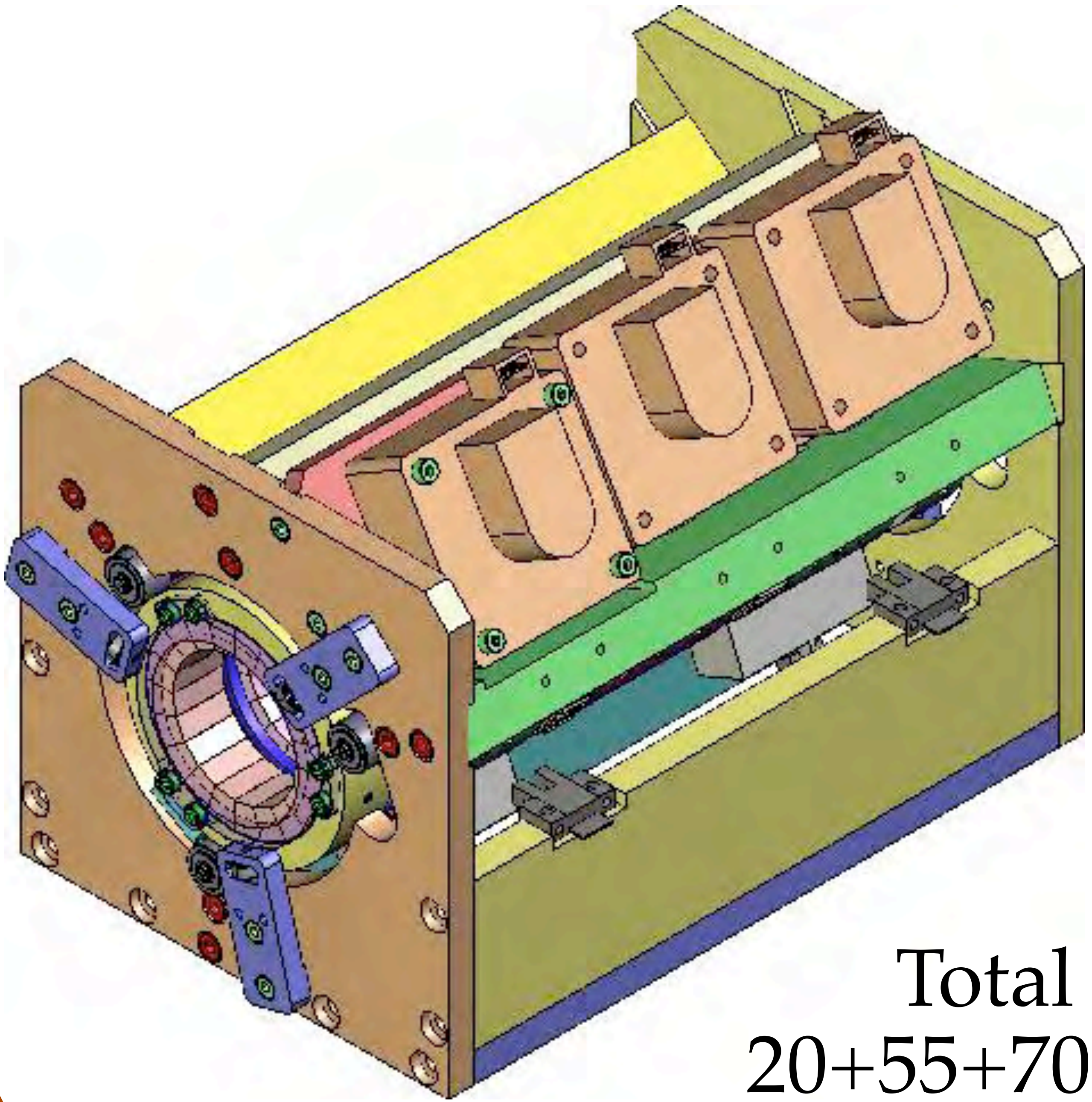
TOSCA calculation

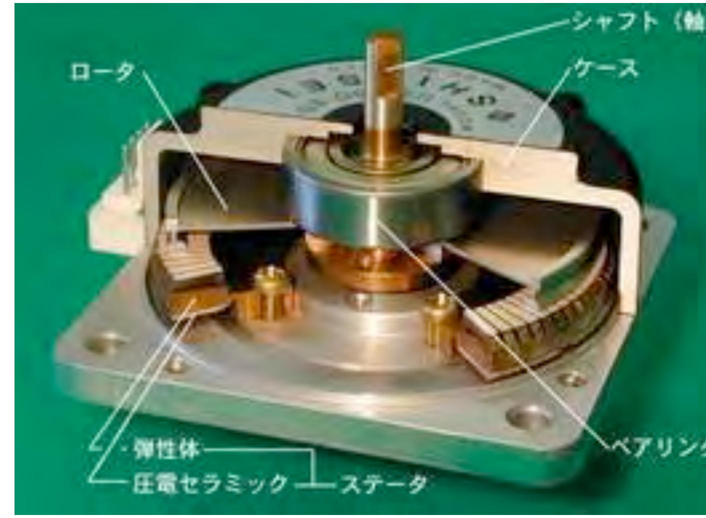


0 deg.

±22.5 deg.

One Module



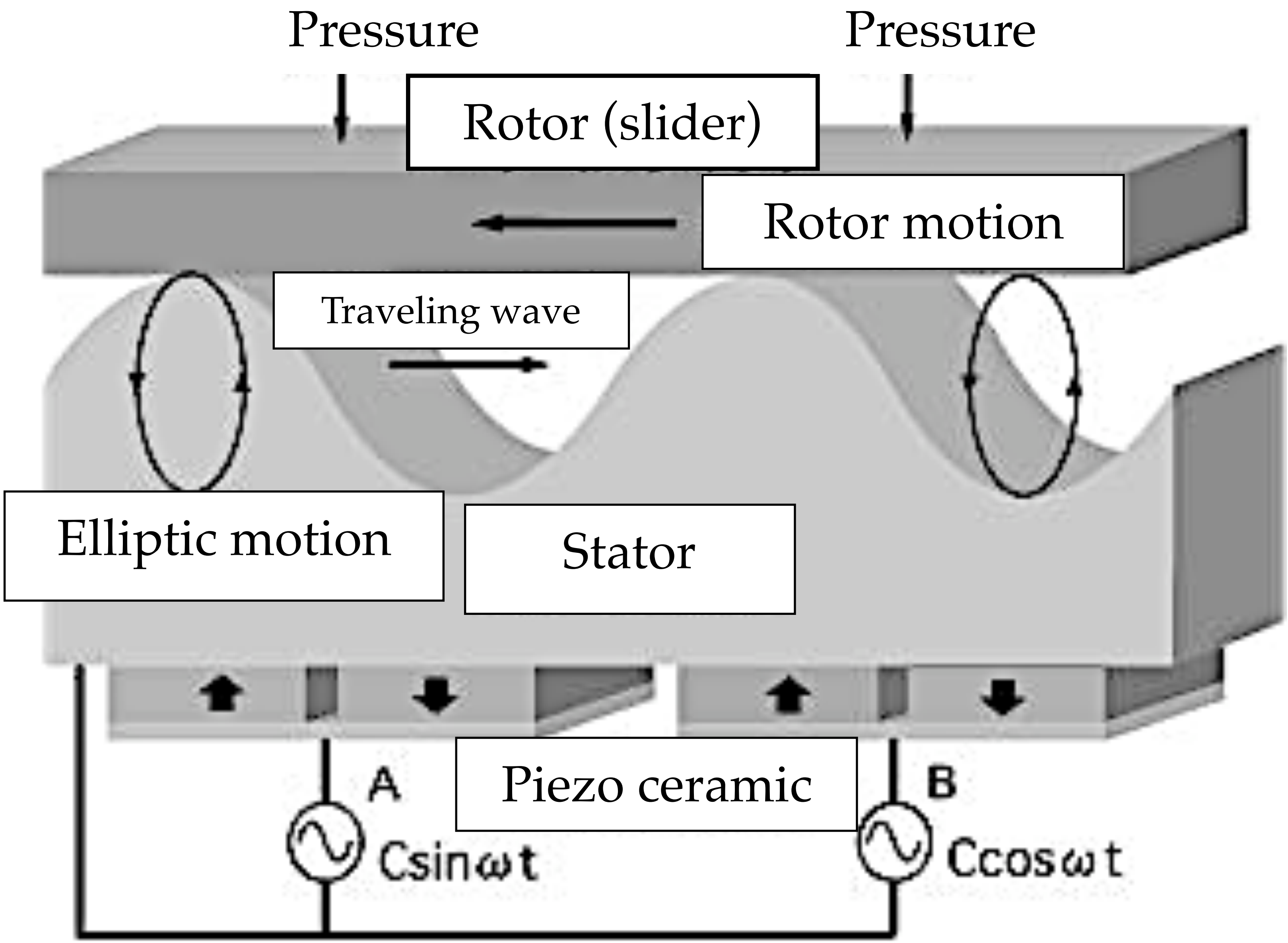


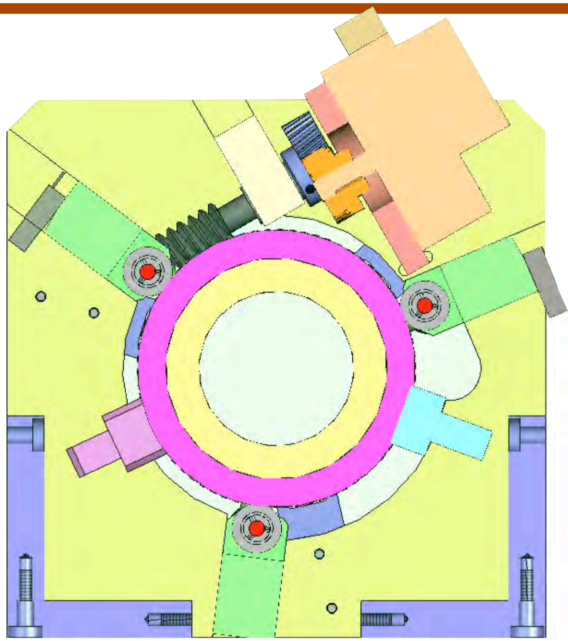
Supersonic Motor (non-magnetic)

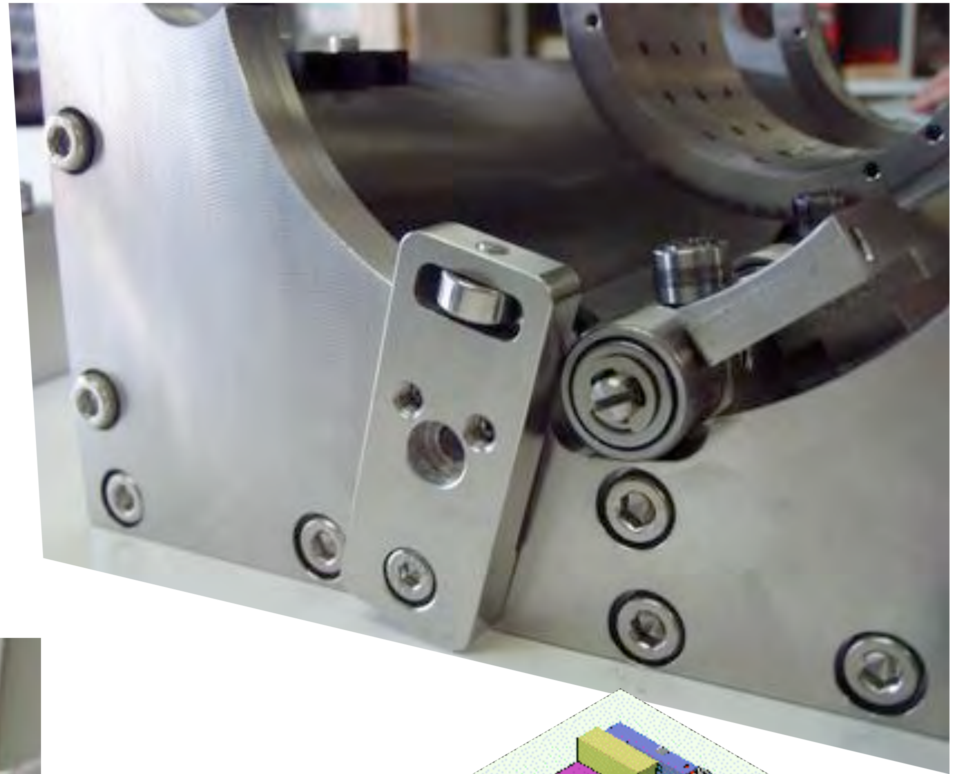
Total length: 260mm

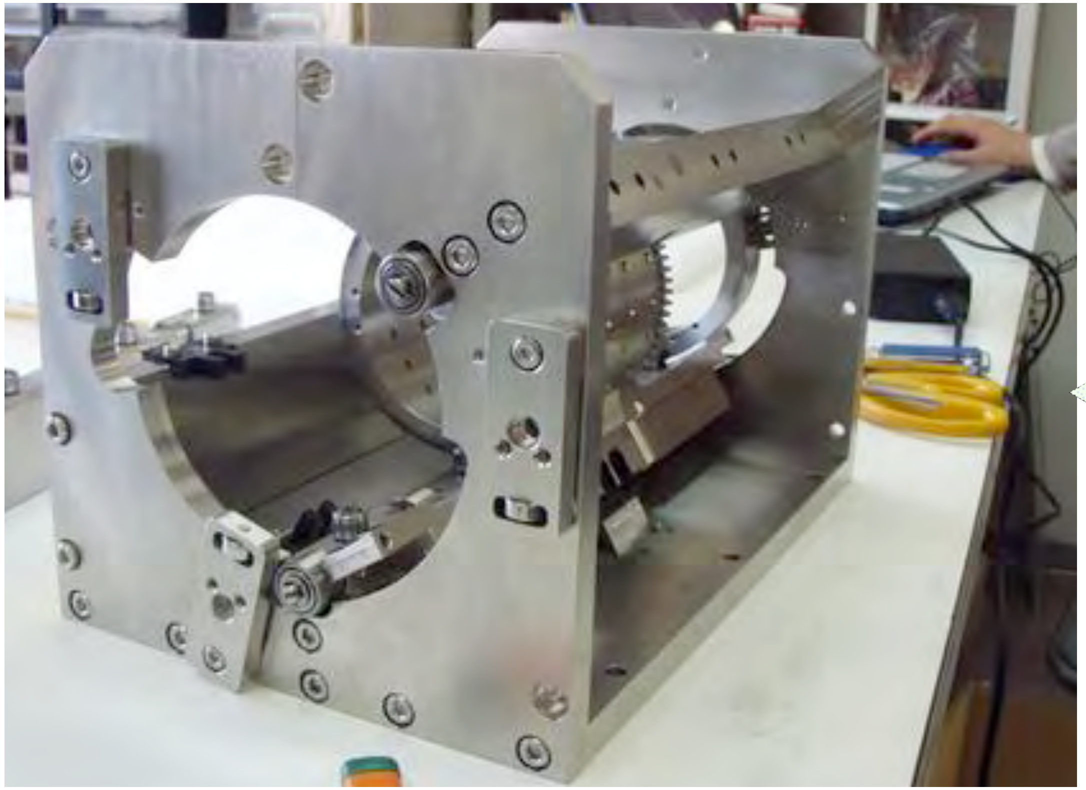
20+55+70+55+20 = 220

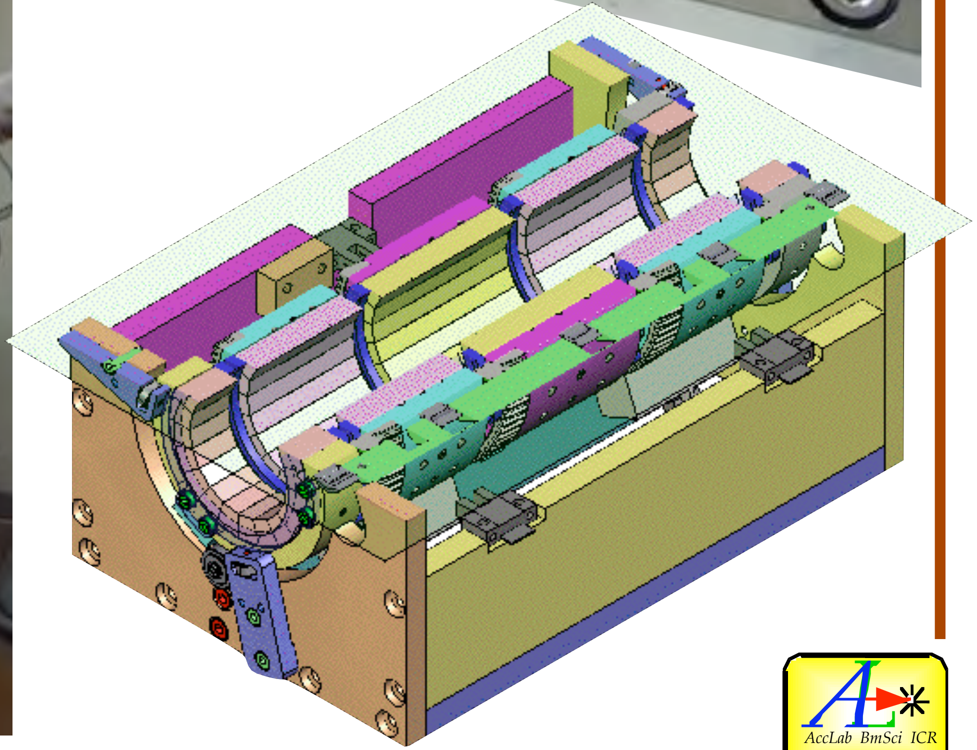
Supersonic Motor (non-magnetic)



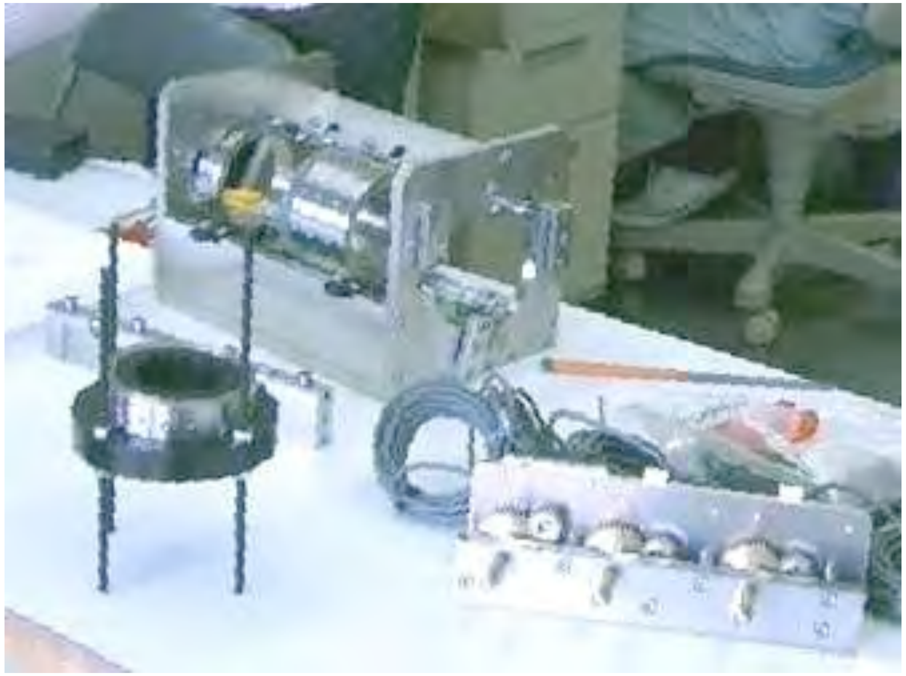


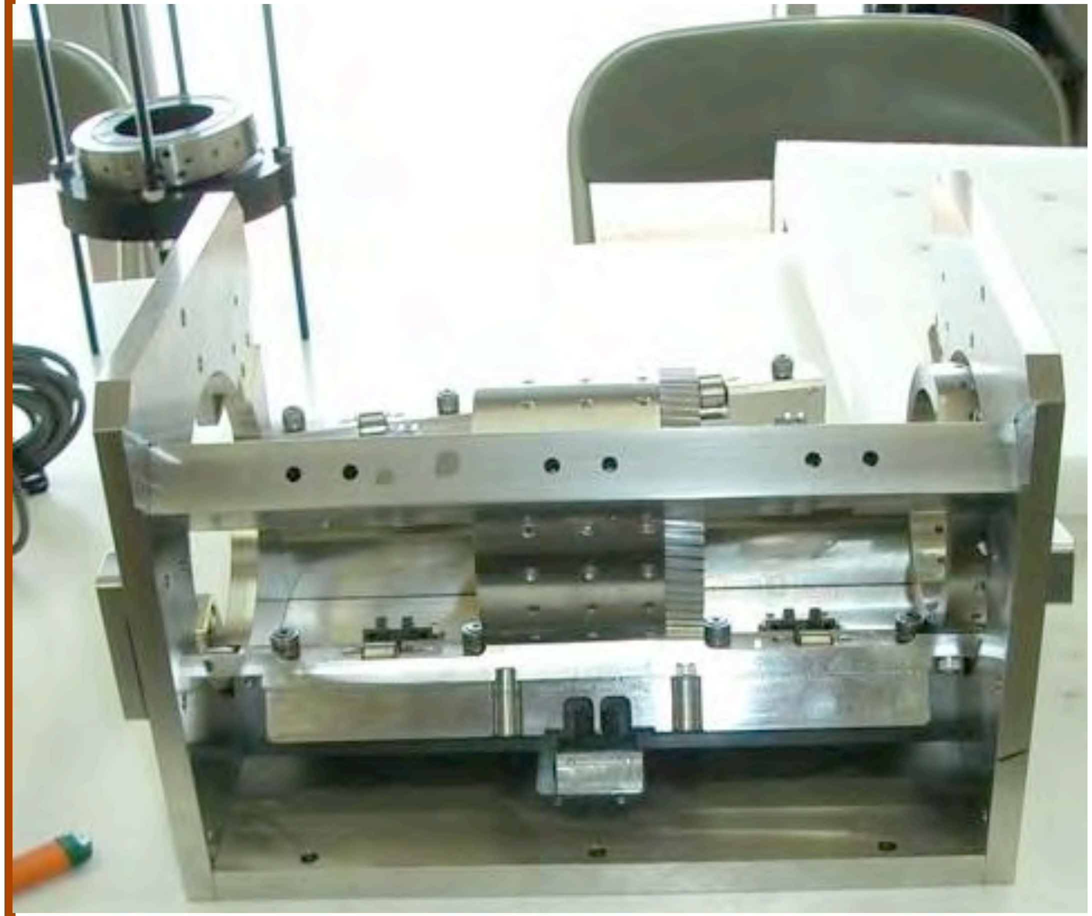




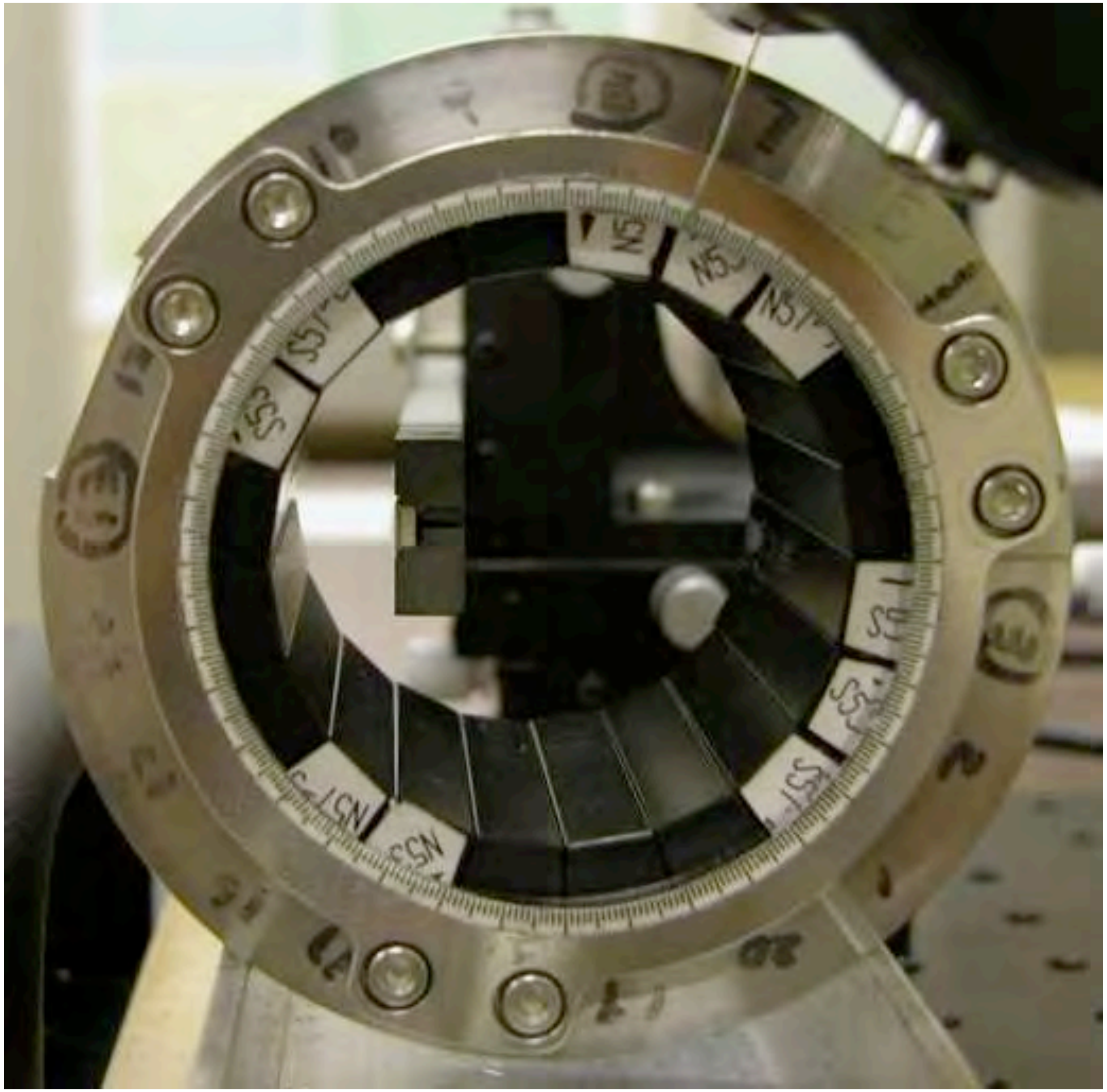


The Parts

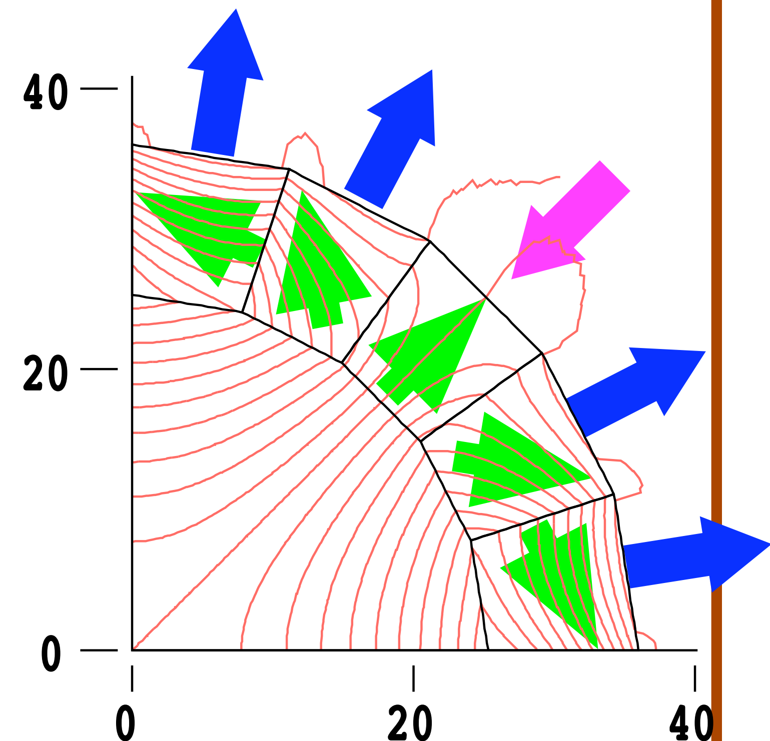




Magnet Bore



Pole magnets are attracted.



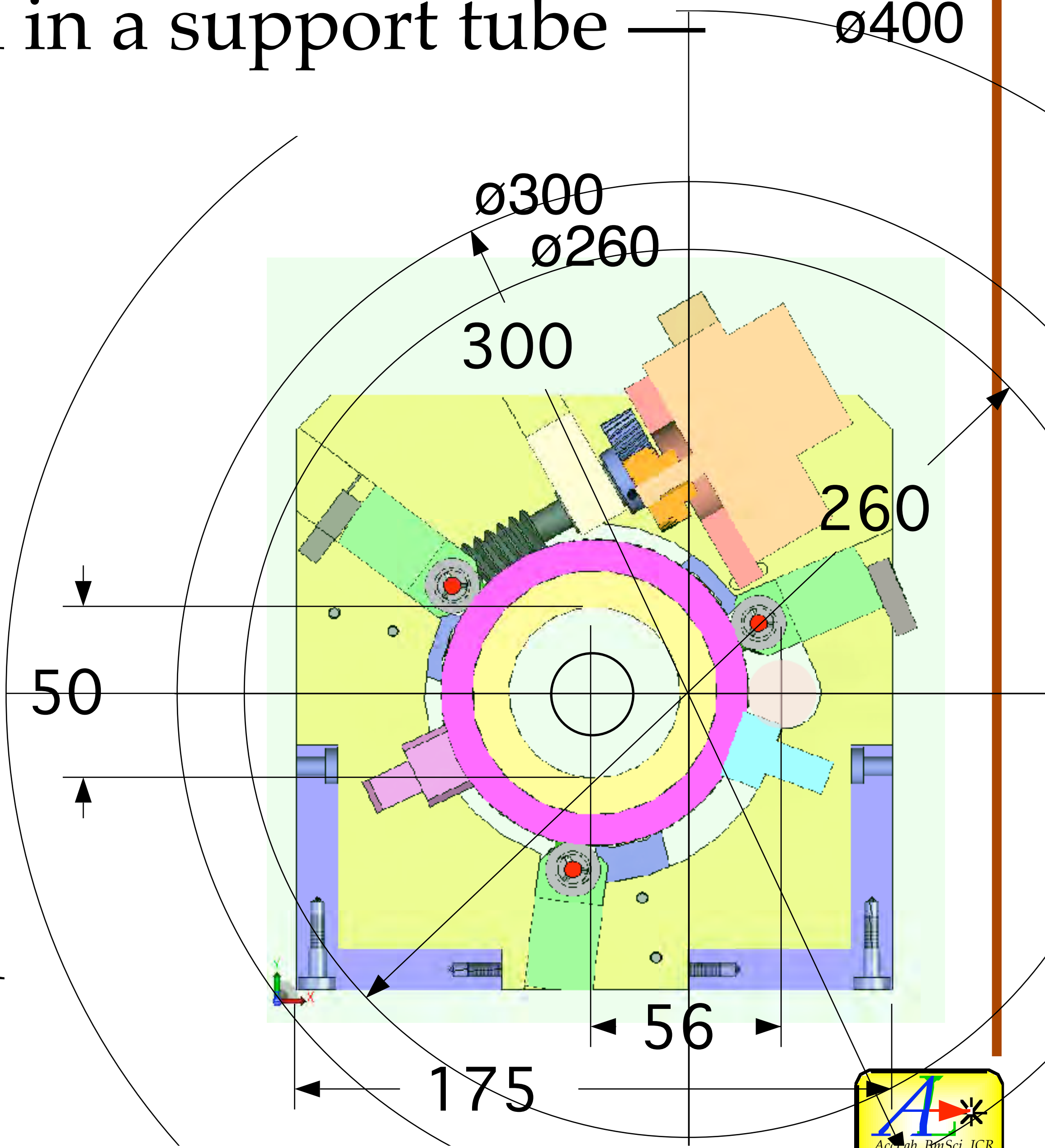
Others are repulsive.

Alignment Jig

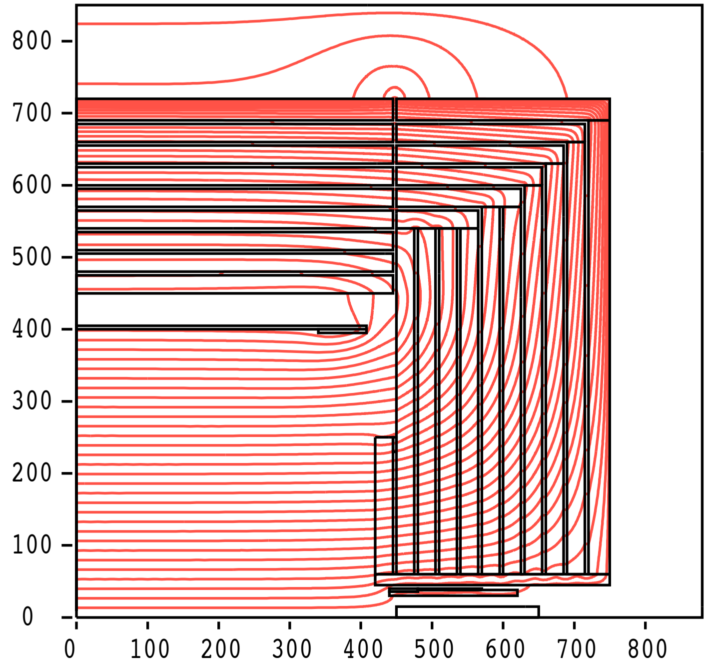
Cross Section

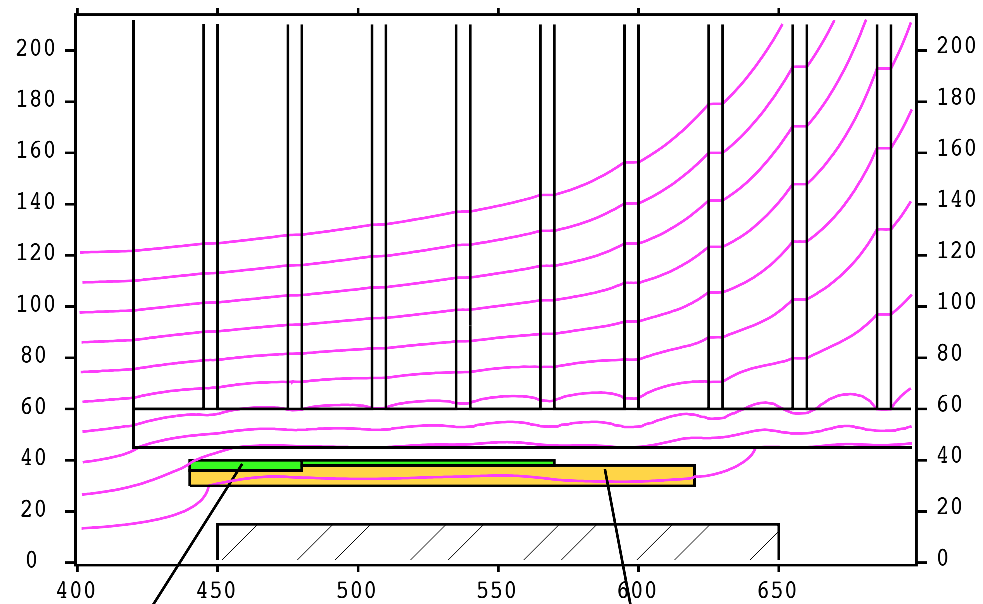
— ATF2 version in a support tube —

- Separation:
  - 14mr x 4.0 = 56mm
  - 14mr x 4.5 = 64mm
  - 14mr x 5.0 = 70mm
- Corners may be cut.
- No magnetic mat'l.
- SS Motor.
- Mover to be installed
- How to support?



Rough Calculation

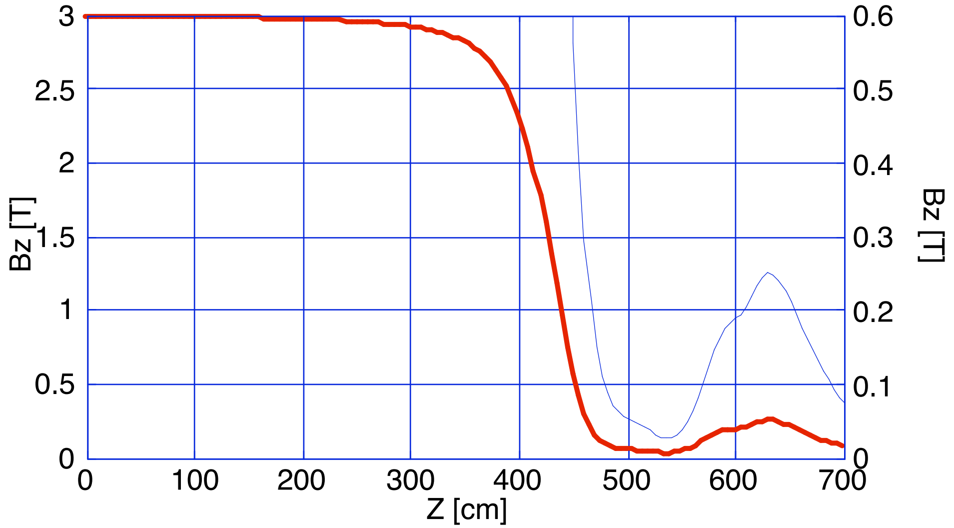




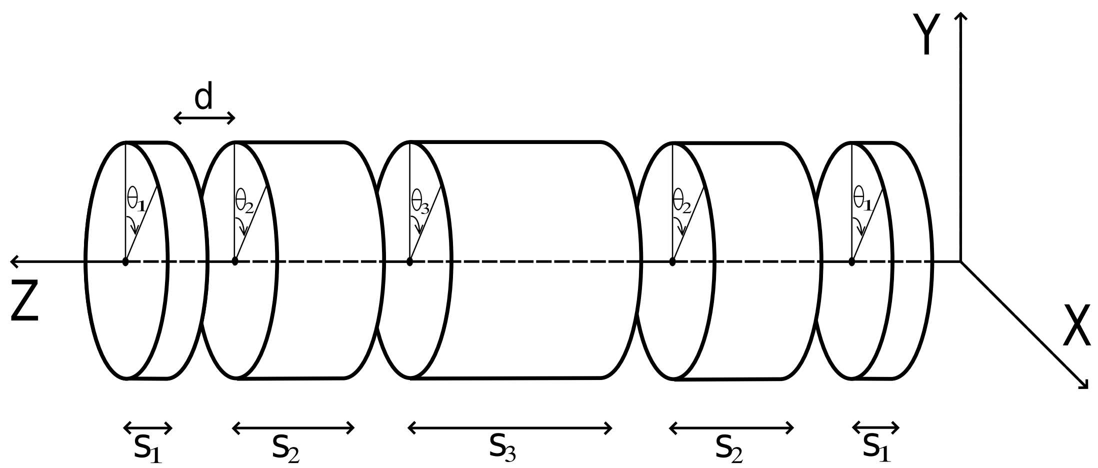
3kA/cm² 2.82E5 -5.31E4 [N]

iron shield
-1.08E5 [N]
= 12t

GLDFFAS



Gluckstern's variable PMQ



Definitions and the ratio:

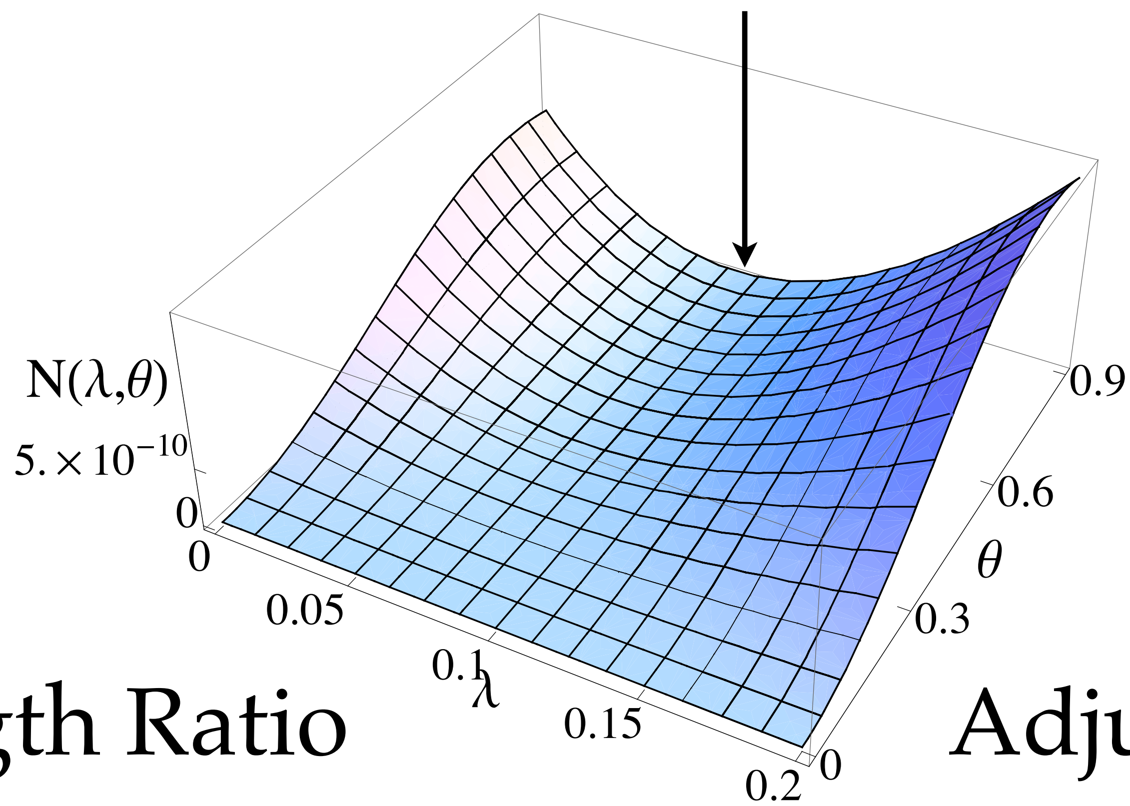
$$2s_1 - 2s_2 + s_3 = 0, \qquad 2s_1 + 2s_2 + s_3 \equiv S, \qquad s_1 \equiv \lambda S$$

$$\theta \equiv \theta_1 = -\theta_2 = \theta_3, \qquad \mu \equiv kS$$

$$\theta_1 = \theta, \qquad \theta_2 = -\theta, \qquad \theta_3 = \theta$$

$$\Rightarrow \qquad s_1 = \frac{\lambda\mu}{k}, \qquad s_2 = \frac{\mu}{4k}, \qquad s_3 = \frac{\mu - 4\lambda\mu}{2k} \qquad (1)$$

Square sum of off-diagonal elements becomes minimum at λ ~ 0.078781



Length Ratio

Adjusting Angle

Fig. 3: plot of N(λ , θ)

Effect of errors : a slight slip on each disc

S matrix with a slight slip, for instance on 1st disc

$$\mathbf{M}_{vPMQ}{}' = \mathbf{M}_{RQR}(s_1, k, \theta) \cdot \mathbf{M}_{DS}(d) \cdot \mathbf{M}_{RQR}(s_2, k, -\theta) \cdot \mathbf{M}_{DS}(d) \cdot \mathbf{M}_{RQR}(s_3, k, \theta) \cdot \mathbf{M}_{DS}(d) \cdot \mathbf{M}_{RQR}(s_2, k, -\theta) \cdot \mathbf{M}_{DS}(d) \cdot \mathbf{M}_{RQR}(s_1, k, \theta + \delta)$$

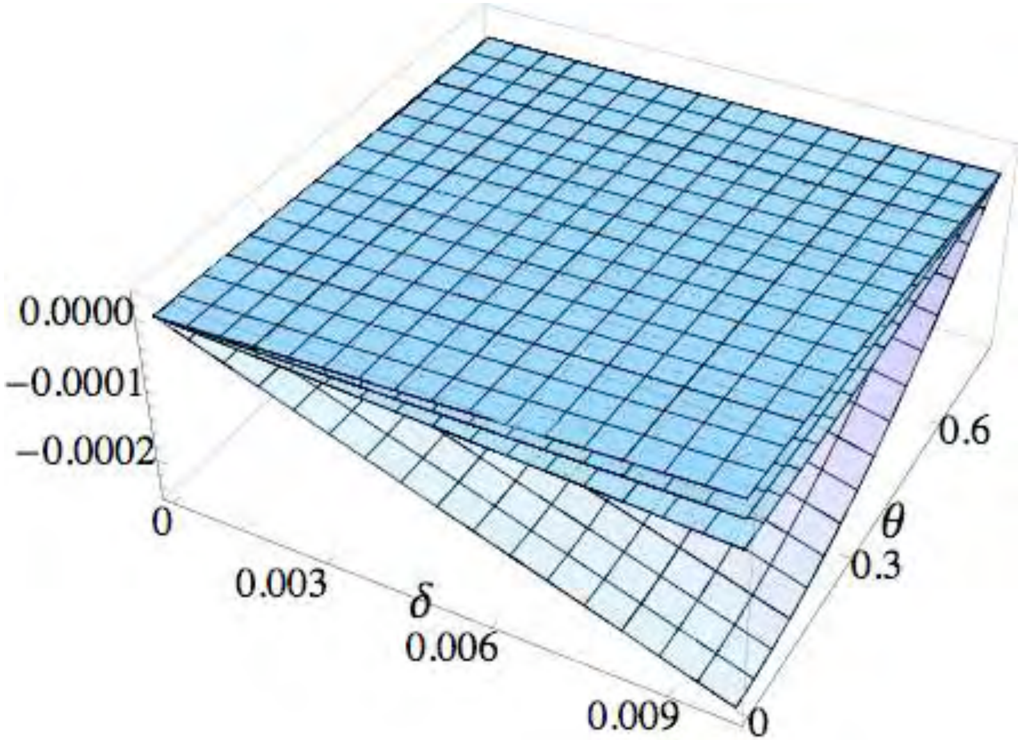


Fig. 4: OD elements of ΔM_Q with a slight slip on 3rd disc

Beam size at IP of ILC

$$\frac{\sigma_x}{\sigma_y} = \frac{656[nm]}{5.44[nm]}$$

For $\delta < 0.01$ [rad], $\Delta M_Q < 10^{-3}$

To be considered (1st) for ILC

- The first version (double ring structure):
  - ☑ Soft magnet inside.
  - ➡ Antisolenoid (Full cancellation) is needed where Superconducting Mag. brings vibration fear. But may be small effect on beam.
  - ➡ Large repulsive force ~200kN to be supported.

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To be considered (2^{nd}) for ILC

- The second version (five-ring-singlet):
  - ☑ No soft magnet.
  - ➡ Antisolenoid is still needed but partial. Vibration from Superconducting Mag. may be small effect on beam. (HTc coil?)
  - ➡ Magnetic force should be small.
  - Demagnetization resistance has to be checked.
  - Effect on beam of μ=1.05 has to be checked.
  - What about SD0?

Appendix

Demagnetization by Radiation

Energy deposit

	GLD	SiD	SiD (by Takahashi)	neutron
BeamCAL	17mW	13mW	29mW	
QD0	94mW	97mW	147mW	10^5 [n/cm^{2}s]
SD0	11mW	11mW	11mW	
QF1	16mW	18mW	15mW	
SF1	0.4mW	0.3mW	1mW	

very preliminary results by T.Abe (University of Tokyo), in private communication

Demagnetization by 14MeV neutron

Magnet	Demag. ratio [/1x10^{13}n/cm^2]	iHc [Oe]
47H	10.2%	
44H	1.8%	16
39SH	0.7%	21
32EH	0.3%	30

T. Kawakubo, et al., The 14th Symposium on Accelerator Science and Technology, Tsukuba, Japan, November 2003, pp. 208-210, in Japanese, http://conference.kek.jp/sast03it/WebPDF/1P027.pdf

Continuous 1mo.(2.6x10^6s) operation may cause about 0.01[%] of (reversible?) demagnetization on NEOMAX 32EH. (1% for 10 years) ... needs more info.

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